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NAEW Publication List Related to Surface Mines

Publications and abstracts are listed in reverse chronological order. A limited number of reprints are available, and can be requested by referring to the NAEW number. Use your browser's "find" feature to search for words of interest. For more information, please contact:

James V. Bonta
Research Hydraulic Engineer
N. Appalachian Experimental Watershed
PO Box 488
Coshocton, Ohio 43812
USA

email: jim.bonta@ars.usda.gov
phone: 740-545-6349
fax: 740-545-5125

Shipitalo, M.J., Bonta, J.V. 2008. Impact of using paper mill sludge for surface-mine reclamation on runoff water quality and plant growth. Journal of Environmental Quality. 37(6):2351-2359. **(NAEW # 458 – Available in PDF file)**

Abstract
Paper mills generate large amounts of solid waste consisting of fibrous cellulose, clay, and lime. Paper mill sludge (PMS) can improve reclamation of surface-coal mines where low pH and organic-carbon levels in the spoil cover material can inhibit revegetation. When applied at high rates, however, PMS may adversely impact the quality of surface runoff. Therefore, we applied PMS at 0, 224, and 672 dry Mg ha−1 to 22.1 × 4.6-m plots at a recently mined site and monitored runoff for a total of 13 mo. The zero-rate plots served as controls and received standard reclamation consisting of mulching with hay and fertilization at planting. Compared to the control plots, PMS reduced runoff fourfold to six fold and decreased erosion from 47 Mg ha−1 to <1 Mg ha−1. Most of the reduction occurred in the 2.5 mo before the plots were planted. Flow-weighted average dissolved oxygen concentrations in runoff from plots at the 224 and 672 Mg ha−1 rates, however, were much lower (≤0.4 vs. 8.2 mg L−1) and chemical oxygen demand (COD) was much higher for the 672 Mg ha−1 rate plots than the control plots during the pre-plant period (7229 vs. 880 mg L−1). There were few noteworthy differences in water quality among treatments post-planting, but plant dry-matter yields were greater for the PMS plots than for the controls. The 672 Mg ha−1 rate did not increase COD or nutrient loads compared to the 224 Mg ha−1 rate and may have more persistent beneficial effects by increasing soil organic carbon levels and pH to a greater extent.

Bonta, J.V. 2005. Challenges in conducting hydrologic and water quality research in drastically disturbed watersheds. Journal of Soil and Water Conservation 60(3):121-133. **(NAEW #415 – Available in PDF file)**

Abstract

A nine-year investigation was conducted on the impacts of drastic land disturbances in small watersheds due to coal mining and reclamation activities on surface and subsurface hydrology and water quality. Three small watersheds in Ohio (12 to 18 ha) were monitored before mining, during mining and reclamation, and after reclamation for hydrology and water quality, resulting in many publications. The current increased interest in coal mining may require additional watershed-scale studies on the short- and long-term effects of drastic land disturbances on watershed hydrology, water chemistry, and sedimentation. Conducting watershed-scale studies in drastically disturbed areas is expensive, long-term, high-risk, and difficult research. The challenges and experiences of conducting the nine year study are identified so that other investigators may efficiently plan and conduct similar watershed-scale research in mines. The experimental design of the project, actual conditions

during the project, and challenges in conducting the research are discussed. Hydrological instrumentation must be dependable and operational to collect data from the short duration disturbances because these periods are not repeatable, and watersheds require many years to approach a new equilibrium. Control watersheds must be free from previous disturbances. It was not feasible to quantitatively characterize the watersheds during the rapid and transitory periods of disturbance. Undisturbed and reclaimed watersheds can be visually undisturbed, but hydrologically disturbed. Surface- and groundwater hydrology and water chemistry processes may not reach a dynamic equilibrium until many years have passed. Association of data with periods of disturbance is not precise, depends on available data, and requires scientific judgment. The “drop-box weir” works well for sediment-laden flows with large rocks expected from drastically disturbed areas. Many recommendations are presented for future watershed-scale research on drastic land disturbances. This paper addresses challenges in researching the impacts of mining and reclamation activities but is applicable to studying other land disturbances such as urbanization.

Bonta, J.V. 2005. Changes in concentration-discharge regression parameters due to coal mining and reclamation activities. Hydrological Science Journal 50(1):155-173. **(NAEW #411)**

Abstract

Assessment of the impacts of mining and reclamation, and design of management practices to reduce chemical loads in stream channels, require knowledge of changing hydrologic conditions and of changing sources and rates of release of chemicals into stream waters. One simple method for evaluating these impacts is to combine flow duration curves with regression relations between surface-water chemical concentrations (C) and instantaneous discharge (Q). However, little is known regarding the drainage basin-scale effects of mining and reclaiming drainage basins on changing regression relations. These effects were assessed on three small experimental drainage basins in Ohio subjected to surface mining for coal (C06, M09, and J11). Comparisons were made between regression parameter changes for natural/undisturbed conditions (Phase 1), land disturbances caused by mining and reclamation activities (subphases of Phase 2), incomplete reclamation (subphases of Phase 3), and the final condition of the reclaimed drainage basins (Phase 3F). Regression analysis used a total of 5047 laboratory analyses of 36 constituents. Of 429 regressions, 153 (36%) were statistically significant. Surface runoff diversions left in place during Phase 3F at C06 caused many significant differences between Phase 1 and 3F regressions. The return of regression relations from Phase 3F to premine conditions at M09 is attributed to reclamation consisting of straw crimping and no runoff diversions. The haul-back method of mining at J11 contributed to the observed regression changes due to the diverse surface disturbances of ongoing concurrent mining and reclamation. Statistically significant changes in regressions indicate larger chemical concentrations and loads resulting from these disturbances. The sign of the regression-line slope changed for some constituents from one phase to the next, documenting the changing sensitivity of concentration to low and high flows. Knowledge of changes in regression parameters is important because regressions supply information on the rate of release and supply of chemical constituents in mined and reclaimed drainage basins. Duration curves of concentration and loads can be constructed using these regressions with flow-duration curves to give estimates of the percent of time that concentrations and loads are exceeded during different phases of disturbance. This study assessed the changes in regression relations due to mining coal seams and reclamation activities for 36 chemical constituents, two mining methods, three reclamation practices, and three distinct geologic settings.

Bonta, J.V. 2004. Experiences in instrumentation and conducting investigations of drastic land disturbances in small watersheds. International Instrumented Watershed Symposium, Edmonton, Alberta, CANADA.AVAILABLE: HTTP://WWW.OSERN.RR.UALBERTA.CA/DOWNLOADS/IIWS/BONTA_PAPER.PDF **(NAEW #406)**

Abstract

A seven to nine-year investigation was conducted on the impacts of drastic land disturbances in small watersheds due to coal mining and reclamation activities on surface- and subsurface hydrology and water quality. Three small watersheds (12 to 20 ha) in Ohio were monitored before mining, during mining and reclamation, and after reclamation for hydrology and water quality. The planned experimental design of the project, the actual

conditions during the mining and reclamation activities, and challenges in conducting the research are discussed. Watershed research in surface-mined areas is considered long term, high-risk research. Control watersheds must be free from previous disturbances, which is difficult to document for sites that do not have long hydrologic runoff records. It was not economically feasible to quantitatively characterize the watersheds during the rapid and transitory periods of watershed disturbance. Undisturbed and reclaimed watersheds can be visually undisturbed, but hydrologically disturbed. Surface- and ground-water hydrology and water chemistry processes may not reach a dynamic equilibrium until many years have passed. This study addressed the immediate and most apparent impacts of surface mining and reclamation, but not the more subtle impacts. The utility of, and recent research into, a flow-measuring device called the "drop-box weir" is also presented. This weir is not well known, but works well where commonly used weirs would fail for sediment-laden flows with large particles that are expected from erosion-vulnerable landscapes draining drastically disturbed areas. Recent hydraulic research with the weir extends its utility to small erosion plots and small, steep watersheds. Sampling devices for use with the weir have been developed. The design of the project led to many useful results, in spite of the challenges during the project.

Bonta, J.V. 2004. Concentration-discharge regression parameters in watersheds of varying lithology subjected to surface coal mining and reclamation. Journal of Soil and Water Conservation 59(2):86-101. **(NAEW #398)**

Abstract

Evaluations of the impacts of mining and reclamation require knowledge of changing hydrologic conditions and of changing sources and rates of release of chemicals into stream waters. Not much is known regarding the watershed-scale effects of mining and reclaiming watersheds on relations between surface-water chemical concentrations (C) instantaneous discharge (Q) for different geological settings. These impacts were evaluated on three geologically dissimilar, small experimental watersheds subjected to surface mining for coal (C06, M09, and J11). Comparisons were made across watersheds during similar types of land disturbances during natural/undisturbed conditions (Phase 1), land disturbances caused by mining and reclamation activities (subphases of Phase 2), incomplete reclamation (subphases of Phase 3), and the final condition of the watersheds (Phase 3F). Regression analysis used a total of 5,047 laboratory analyses of 36 constituents. Of 429 regressions, 153 (36%) were statistically significant. More statistically significant regressions using a power equation were found during Phases 1 and 3F at the three sites – relatively stable watershed periods. The stability in log concentration versus log instantaneous discharge relations is quickly achieved for some constituents, mostly for major ions. Constituents for which significant regressions were found across all three watersheds during different phases of watershed disturbance were identified. Signs of the chemical concentrations – instantaneous discharge (C-Q) regression slope parameter (exponent of the power equation) was similar across the three geologically dissimilar watersheds for different phases. This study contains tables that document expected chemical concentrations – instantaneous discharge (C-Q) relations and changes in parameters due to mining coal seams and reclamation activities for 36 chemical constituents, using two mining methods, three reclamation practices, and three distinct geologic settings. The tables also provide guidance for simplified field sampling of streams for correlated and uncorrelated constituents.

Bonta, J.V. and W.A. Dick. 2003. Impact of coal surface mining and reclamation on surface water chemical concentrations and load rates in three Ohio watersheds. J. of the American Water Resources Association 39(4):793-815. **(NAEW #386)**

Abstract

Information is lacking on the watershed-scale effects of mining and reclaiming originally undisturbed watersheds for coal on surface-water chemical concentrations and load rates for a variety of constituents. These effects were evaluated on three small, geologically dissimilar watersheds subjected to surface mining in Ohio. Comparisons were made between phases of land disturbances using ratios of average concentrations and load rates: Phase 1 (natural), subphases of Phase 2 (mining and reclamation), and subphases of Phase 3 (partial reclamation and final condition) using 4485 laboratory analyses of 34 constituents. Average concentration and load-rate ratios were categorized into three classes - minor, moderate, and substantial. Mining and reclamation (M/R) affected flow-duration curves in different ways - baseflow changes were variable but high flows generally increased. The average concentration ratios for all sites were classified as 15% “minor,” 36% “moderate,” and 49% “substantial”

(average ratio of 2.4.) Generally load-rate ratios increased due to mining and reclamation activities (average ratio of 3.3). Minor, moderate, substantial impacts were found on average for 7%, 23%, and 70% of load-rate ratios. The impact of M/R on average load rates was not necessarily the same as on average concentrations due to changed hydrology, and can be opposite in effect. The evaluation of the impacts of M/R requires knowledge of changing hydrologic conditions and changing supplies and rates of release of chemicals into streams. Median sediment concentration ratio is an indicator of average constituent load rate ratio of a wide variety of chemical constituents, and is useful for development of best-management practices to reduce chemical loads. The site at which diversion ditches were not removed during final reclamation sustained large chemical load rates, and removal of diversions at the other mined site reduced load rates. Revegetation of poorly reclaimed areas decreased chemical load rates. Chemical load rates were sensitive to geology, mining and reclamation methods, diversions, and changing hydrology, concentration-flow rate regressions, and watershed areas.

Bonta, J.V. 2000. Runoff-Energy Factors for MUSLE Sediment-Yield Model for Surface Mines. International Journal of Sediment Research 15(2):162-181. **(NAEW #359)**

Abstract

The Modified Universal Soil Loss Equation (MUSLE) is often used for sediment-yield estimations in surface mines for design and impact evaluations. However, it is not known if the widely-used runoff-energy factor of MUSLE is appropriate, or if its parameters are the same for surface mines as for agricultural watersheds from which MUSLE was developed. Suspended-sediment data from three experimental watersheds in Ohio (approximately 10 - 20 ha), subjected to near complete disturbance due to mining and reclamation, were used to investigate five alternate runoff-energy factors in the MUSLE sediment-yield model for use in surface mines. The evaluation led to the selection of the generalized model form, $a'(\text{runoff volume} \times \text{peak flow rate})^b$, as the best choice among models investigated. Exponent b was greater than the widely-used value of 0.56, ranging from 0.68 to 1.10. Parameter b was dependent on whether mining- or reclamation-related watershed activities were predominant. The original Williams (1975) model fit the data least well of the five energy factors studied.

Bonta, J.V. 2000. Impact of Coal Surface Mining and Reclamation on Suspended Sediment in Three Ohio Watersheds. Journal of the American Water Resources Association 36(4):869-887. **(NAEW #356)**

Abstract

Prior to PL95-87 little research had been conducted to determine the impacts of mining and reclamation practices on sediment concentrations and yields on a watershed scale. Furthermore, it was unknown whether sediment yield and other variables would return to undisturbed levels after reclamation. Therefore, three small watersheds, with differing lithologies and soils, were monitored for runoff and suspended sediment concentrations during three phases of watershed disturbances: undisturbed watershed condition, mining and reclamation disturbances, and post-reclaimed condition. Profound increases in suspended-sediment concentrations, load rates, and yields due to mining and reclamation activities, and subsequent drastic decreases after reclamation were documented. Even with increases in runoff potential, reductions in suspended-sediment concentrations and load rates to below or near undisturbed-watershed levels is possible by using the mulch-crimping technique and by removing diversions. Maximum concentrations and load rates occurred during times of active disturbances that exposed loose soil and spoil to high-intensity rains. Sediment concentrations remained elevated compared with the undisturbed watershed when diversions were not well maintained and overtopped, and when they were not removed for final reclamation. Diversions are useful for vegetation establishment, but should be maintained until they are removed for final reclamation after good vegetative cover is established.

Bonta, J.V., C.R. Amerman, T.J. Harlukowicz, and W.A. Dick. 1997. Impact of Coal Surface Mining on Three Ohio Watersheds - Surface-Water Hydrology. J. of the Am. Water Resources Association 33(4):907-917. **(NAEW #334)**

Abstract

A study was conducted to determine the effects of mining and reclaiming originally undisturbed watersheds on surface-water hydrology in three small experimental watersheds in Ohio. Approximately six years of data were

collected at each site, with differing lengths of premining (Phase 1), mining and reclamation (Phase 2), and post-reclamation (Phase 3) periods. Mining and reclamation activities showed no consistent pattern in baseflow, and caused slightly more frequent higher daily flow volumes. Phase 2 activities can cause reductions in seasonal variation in double mass curves compared with Phase 1. Restoration of seasonal variations was noticeable apparent at one site during Phase 3. The responses of the watersheds to rainfall intensities causing larger peak flow rates generally decreased due to mining and reclamation, but tended to exceed responses observed in Phase 1 during Phase 3. Natural Resources Conservation Service (NRCS) curve numbers increased due to mining and reclamation (Phase 2), ranging from 83 to 91. During Phase 3, curve numbers remained approximately constant from Phase 2, ranging from 87 to 91.

Bonta, J.V. 1993. Review of the Effects of Surface Coal Mining on Hydrology and Water Quality of Three Ohio Watersheds. Hydrological Science & Technology 9(1-4):54-88. **(NAEW #303)**

Abstract

A study was conducted to determine the effects of mining and reclaiming originally undisturbed watersheds on surface- and ground-water hydrology and quality in three small experimental watersheds in Ohio. Approximately 6 years of data were collected at each site, with differing lengths of premining (Phase 1), mining and reclamation (Phase 2), and post-reclamation (Phase 3) periods. Mining and reclamation activities impaired baseflow and caused more frequent higher daily flow volumes. Phase 2 and early Phase 3 periods caused noticeable reductions in seasonal variation in double mass curves compared with Phase 1. However, seasonal variations were restored to some extent. Mining and reclamation increased peak-flow rates per unit of causal rainfall intensity compared to premine conditions, and did not return to premine levels during Phase 3. Soil Conservation Service curve numbers increased due to mining and reclamation to values in the curve number range, 83 to 90. During Phase 3, curve numbers slightly increased to the range, 87 to 91.

At two sites mining and reclamation resulted in elevated concentrations of many constituents, but concentrations generally did not change significantly at another. Sediment concentrations significantly increased from Phases 1 to 3, and then decreased after vegetation establishment. Water and sediment chemistry were significantly affected by geologic composition of the watersheds.

Mining disturbances in watersheds adjacent to the experimental sites affected ground-water levels in the undisturbed experimental watersheds prior to actual mining in the experimental sites. New subsurface flow paths, with different characteristics, formed during mining and reclamation. At all three sites mining dewatered the saturated zone above the underclay of the mined coal seam. Mining and reclamation affected ground-water levels below the mined coal seam in the middle and lower zones within at least two sites. Ground-water level recovery in the mined upper saturated zone was slow and irregular both temporally and spatially after reclamation. Hydraulic conductivities of postmining (Phase 3) spoil were generally greater than those of Phase 1 bedrock, but wide spatial variability was observed. Modelers need to be aware of the complexities of new flow paths and physical characteristics of subsurface flow media that are introduced by mining and reclamation, including destruction of the upper-zone clay.

The extensive disturbances of mining and reclamation caused more changes in constituent concentrations in the upper zone groundwater than in lower zones, most of which were statistically significant increases (many were “drastic”). These disturbances also affected ground-water chemistry in lower zones - those that were not physically disturbed; tended to increase the frequency of exceedence of regulated constituents in all saturated zones; and affected the chemistry of surface baseflow water at the watershed outlets. Several constituents were still changing at the end of the project at all sites.

Bonta, J. V., C. R. Amerman, W. A. Dick, T. J. Harlukowicz, and A. C. Razem. 1992. Impact of Surface Coal Mining on Three Ohio Watersheds - Ground-Water Chemistry. Water Resources Bulletin 28(3):597-614. **(NAEW #291)**

Abstract

A study was conducted to determine the effects of surface mining and reclamation on ground-water chemistry in three saturated zones in each of three small East-Central Ohio watersheds. The extensive disturbances of

mining and reclamation: (1) caused more changes in constituent concentrations in the upper zone than in lower zones, most of which were statistically significant increases (many were “drastic”); (2) affected ground-water chemistry in lower zones - those that were not physically disturbed; (3) tended to increase the frequency of exceedance of regulated constituents in all saturated zones; and (4) affected the chemistry of surface baseflow water at the watershed outlets. Several constituents were still changing at the end of the project within all sites and zones.

Bonta, J. V., C. R. Amerman, W. A. Dick, G. F. Hall, T. J. Harlukowicz,
A. C. Razem, and N. E. Smeck. 1992. Impact of Surface Coal Mining on Three Ohio Watersheds - Physical Conditions and Ground-Water Hydrology. Water Resources Bulletin 28(3):577-596. **(NAEW #290)**

Abstract

A study was conducted over a six-year period in East-Central Ohio to determine the effects of surface mining and reclamation on physical watershed conditions and on ground-water hydrology in three ground-water zones in three small experimental watersheds. Mining disturbances in watersheds adjacent to the experimental sites affected ground-water levels in the undisturbed experimental watersheds prior to actual mining in the experimental sites. New subsurface flow paths, with different characteristics, formed during mining and reclamation. At all three sites mining dewatered the saturated zone above the underclay of the mined coal seam. Mining and reclamation affected ground-water levels below the mined coal seam in the middle and lower zones within at least two sites. Ground-water level recovery in the mined upper saturated zone was slow and irregular both temporally and spatially after reclamation. Hydraulic conductivities of postmining (Phase 3) spoil were generally greater than those of Phase 1 bedrock, but wide spatial variability was observed. Modelers need to be aware of the complexities of new flow paths and physical characteristics of subsurface flow media that are introduced by mining and reclamation, including destruction of the upper-zone clay.

Bonta, J. V., T. A. Van Echo, and V. T. Ricca. 1991. Erosion and Runoff Control using Bulldozer Imprints on Surface-Mine Spoil. Trans. of the ASAE 34(1):97-105. **(NAEW #283)**

Abstract

Bare surface-mined areas are susceptible to severe erosion and erosion-control practices are required, especially when vegetative cover is being established. A study using simulated rainfall was conducted to evaluate the effects of three erosion-control treatments which manipulate microtopography and can be easily applied with a track-type bulldozer. Treatments were evaluated in which spoil was backbladed, and track cleat marks were imprinted in spoil parallel and perpendicular to the slope (corresponding to bulldozer movement perpendicular and parallel to the slope direction, respectively). Tracks imprinted along the contour of the slope were effective in controlling erosion during a series of three severe storms, but runoff control diminished as the storms were applied. Backbladed plots yielded the highest runoff and soil losses. Operating bulldozers to imprint track marks along the contour on long slopes (bulldozer movement up and down the slope) should be done with a supporting practice, such as diversions.

Dick, W. A., J. V. Bonta, and F. Haghiri. 1986. Chemical Quality of Suspended Sediment from Watersheds Subjected to Surface Coal Mining. J. of Environ. Qual. 15(3):289-293. **(NAEW #255)**

Abstract

The chemical quality of suspended sediment in surface water runoff, which is changed as a result of surface coal mining activities, may influence water quality and have effects where the sediment is deposited downstream from the mine site. Suspended sediment samples were collected from three small watersheds in east-central Ohio prior to, during, and after surface mining and reclamation. The chemical quality of the suspended sediment was determined by measuring Ca, Mg, Fe, Al, Mn, Ni, Pb, Cd, Cu, Zn, Sr, P (following pretreatment of the sample with 30% H_2O_2 and extraction with 0.3 MHCl), acetate-soluble SO_4, pH, organic C, and Hg. Differences in concentrations of parameters were observed among the three watersheds and were related to the composition of the overburden material. At Watersheds C06 and M09, the concentrations of the chemical parameters in suspended sediment samples, collected after reclamation had been completed, were not significantly (P = 0.05)

different than concentrations measured prior to surface mining. An exception was the concentration of organic C, which was lower during the postreclamation period. The concentrations of Mg, Fe, and Al were significantly greater at Watershed J11 during the postreclamation period compared to the premine period which P, organic C, Mn, and Pb concentrations were significantly lower. Concentrations of parameters in suspended sediment samples collected concurrently at the inlet and outlet of the sediment ponds at Watersheds C06 and M09 were not significantly (P = 0.05) different. However, due to settling of the larger and heavier sediment particles, a trend toward increased concentration of parameters in sediment samples collected at the pond outlet compared to the pond inlet occurred at both Watersheds C06 and M09.

Dick, W. A., J. V. Bonta, F. Haghiri, and J. R. Page. 1983. Stream Water Quality of Two Small Watersheds as Affected by Surface Coal Mining. J. Environ. Qual. 12(3):351-358. **(NAEW #241)**

Abstract

Two small watersheds in east-central Ohio were selected for investigation of stream water quality prior to, during, and after surface coal mining and reclamation. Watershed C06 contained sandstone and shale overburden, and Watershed M09 contained limestone, sandstone, and shale. Water quality was monitored by measuring 39 parameters in the stream-water samples collected. Duration curves for the four parameters regulated by the Office of Surface Mining (OSM) showed that most samples collected from the two study watersheds exceeded the 70 mg L^{-1} regulation level for suspended solids concentration. Approximately 50 and 30% of the water samples collected at Watershed C06 during the mining and reclamation period and the post-reclamation period, respectively, exceeded the regulation level (4000 µg L^{-1}) for manganese (Mn). Twenty percent of the pH values at Watershed C06 during the mining and reclamation period were also below the lower regulation level (pH 6). Concentrations of the major cations and anions, suspended solids, and dissolved solids were correlated with flow rate (log values) during the premine and post-reclamation periods. Samples collected at similar flow rates at Watershed M09 showed concentrations of parameters were either not significantly affected or decreased in the post-reclamation samples, compared with the premine samples. A similar comparison for samples collected at the C06 watershed showed parameter concentrations were generally higher during the post-reclamation period. Parameters which were not detected in any samples collected from the two watersheds were arsenic (As), chromium (Cr) VI, mercury (Hg), and sulfide (S^{2-}), while cyanide (CN^{-}) was not detected at M09. Parameters that were only rarely detected were antimony (Sb), cadmium (Cd), lead (Pb), zinc (Zn), silver (Ag), copper (Cu), phenols, and phosphorus (P).

Dick, W. A., J. V. Bonta, and F. Haghiri. 1983. The Impact on Water Quality of Surface Mining for Coal. Ohio Report. 68(6):91-94. **(NAEW #245)**

Abstract

Coal is one of our country's greatest resources. Each year thousands of tons of coal are extracted from the earth in Ohio and throughout the Appalachian region. Energy demands in the future are expected to increase the amount of coal that will be mined. Land disturbed by surface mining for coal can have profound effects on the quality of surface water draining from the mine. This water can then affect areas downstream from the mine site.

To evaluate whether the quality of water can be returned to its pre-mine condition after surface mining and reclamation activities have occurred was one goal of a study initiated in east-central Ohio in 1975. Briefly, this study required a complete description of two small watersheds before mining began and the monitoring of water quality parameters before surface coal mining, during active mining and reclamation, and after reclamation was completed. These two watersheds were subjected to near 100% disturbance as a result of mining during the study period.

List of U.S. Bureau of Mines Open-File Reports

Bonta, J.V. and P. Sutton. 1983. Erosion and Reclamation Plots: Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. U.S. Bureau of Mines Contract Report, 60 pp.

Abstract

An erosion, reclamation plot experiment consisting of 18 plots of one length, four slopes, three topsoil depths, and three mulch rates was conducted over a 2-year period. Analysis of the fallow plot data showed that a topsoiled surface significantly decreased soil loss, but was of borderline significance in affecting peak flow, when compared to spoil. The application of 1 and 2 t/Ac of mulch significantly reduced soil loss 3.8 and 10 times, respectively, as compared with no-mulch plots, but was only of borderline significance in explaining runoff and peak flow changes. Topsoil and spoil USLE slope (S)-factor equations showed remarkable similarity. They were positioned well below the normally used USLE equation indicating that the USLE may over-predict soil losses for the same slope on mine soils. Vegetating and mulching a bare area significantly decreased peak flow and soil losses. The presence or absence of topsoil and its depth appeared to be irrelevant when hydrologic and soil loss variables are considered when fertilization in accordance with soil tests is practiced.

Straw mulch rates of 0, 1, and 2 t/Ac and topsoil depths of 0, 6, and 12 inches were applied in nine treatment combinations to reclamation plots. Treatment effects on vegetative establishment and growth were measured over a two year period. Mulch rates increased plant growth and vegetative canopy cover of the soil surface most during the vegetative establishment period. When the plots were prepared and seeded a second time, plant growth differences were smaller. After plant establishment, mulch cover of the soil-surface was not significantly increased by mulch treatments. Plant dry-matter yields were significantly increased by applying straw mulch but the differences between the 1 and 2 t/Ac rates were small. Topsoil depths had no significant effect on vegetative cover and dry-matter yields.

U.S. Bureau of Mines. 1984. Final Report: Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. U.S. Bureau of Mines Open-File Report, 35 pp.

Abstract

An investigation of surface mining and reclamation in the coal mining region of Ohio resulted in: 1) two simulation models, one for the parts of the land phase of the hydrologic cycle above the water table, the other for ground water in the perched water table configuration of the region, and 2) showing that a) surface mining and reclamation increase runoff and peak flow rates and that these quantities stay high after reclamation, b) sediment concentrations rise by several orders of magnitude during periods of active landscape disturbance but can fall back to premine levels with successful reclamation of a site, c) destruction of perched aquifers above coal underclays reduces or stops dry-weather streamflow, d) aquifers redevelop slowly in the spoils, both over the underclay from which the coal has been removed and over the old land surface downslope where spoil was deposited by regrading operations, and e) higher sulfate concentrations develop in the aquifers where they reside on top of the underclays, but water in spoil over old land surfaces develops as a calcium bicarbonate type. At most, two years of the postreclamation condition were observed at any site, and parameters being monitored were still changing at the end of observations.

Results obtained from an investigation of the effects of surface mining and reclamation in several small watersheds in the coal mining region of Ohio were: 1) mulched seeding with or without topsoil on top of graded spoil were found to be effective in reestablishing vegetative cover when both media were limed and fertilized in accordance with soil tests; 2) stripping, stockpiling, and replacing topsoils generally resulted in a higher percentage of coarse fragments in the reclaimed soil, but similar pH levels when compared to premine soils except that in sandstone-shale terrain some toxic spots remained at the surface after topsoiling; 3) spoil materials in limestone-shale terrain exhibit average pH values similar to those of the original subsoil; in sandstone-shale the averages are also similar, but are more variable and have zones of much lower pH than in the original subsoil; 4) surface-water chemical quality depended on the nature of the rock in the original overburden, but presented few problems after reclamation, the primary problems being that sulfate was increasing at all sites at the end of observations; and 5) sediment quality was poorest at the sandstone-shale sites prior to replacement of the topsoil.

U.S. Bureau of Mines. 1983c. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining: Hydrologic and Water Quality Conditions Prior to and during Mining and Reclamation in a Small Watershed, Jefferson County, Ohio. U.S. Bureau of Mines Open-File Report 209-84, NTIS #PB 85-149276, 177 pp.

Abstract

A 29-acre eastern Ohio watershed was monitored for a five-year period beginning in 1977. During a six-month period in 1980, coal was removed from the watershed. Reclamation was performed in stages over the subsequent two years, but erosion control system failures prevented the detection of any sediment control improvement as a result of reclamation. The lag between the beginning of rainfall and the beginning of runoff decreased after mining began and exhibited much higher peak rates than during the premine period. Reclamation did not result in a return to premine runoff characteristics either during storm periods or between storm periods. Premine baseflow was a result of discharge from a saturated zone supported by the slowly permeable clay under the coal. Coal removal involved dewatering of this zone and the consequent cessation of baseflow. The saturated zone had begun to reestablish as observations ended, but baseflow had not begun.

Soils on the premined landscape were developed in local bedrock units with varying amounts of loess. The postreclamation watershed was mapped as various slope classes of the Fairpoint soil series. Locally within the watershed were small areas of very acid soils, as well as soils with carbonates throughout the solum. Water quality was monitored by measuring 38 parameters in 54 water samples. Thirty-seven samples had suspended solids concentrations which exceeded the OSM regulation level of 70 mg/l. The highest concentrations occurred during the mining and reclamation activities. Four samples had values below and one sample exceeded the OSM regulation levels for pH (6.0) and manganese (4 mg/l), respectively. All samples were below the OSM regulation level for iron (7 mg/l). Concentrations of calcium, magnesium, sulfate, dissolved solids, and suspended solids were greater after the watershed had been partially reclaimed than during the premine period.

U.S. Bureau of Mines. 1983b. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase 3: Hydrologic and Water Quality Conditions after Reclamation in a Small, Mined Watershed, Coshocton County, Ohio. U.S. Bureau of Mines Open-File Report 39-84, NTIS #PB 84-165893, 177 pp.

Abstract

Surface mining and reclamation of a southeastern Ohio site with sandstone-shale overburden resulted in (as compared to premining levels): 1) runoff volumes and peak rates that increased by a factor of from 2 to 10 during mining and after reclamation, 2) destruction of the “aquifer” perched on the underclay of the mined coal bed and gradual, but, as yet incomplete redevelopment of this aquifer after reclamation, 3) no immediate effect on another, lower perched “aquifer”, 4) up to 100 times greater sediment concentrations in runoff. Results were influenced by increasing annual precipitation amounts through the period of record; 1978, 1979, and 1980 (postreclamation years) experienced precipitation amounts approaching or exceeding long-term normalcy for the area. Part of the reason that the site produced more runoff after reclamation than before mining is that the premine condition was one of an open, porous soil under woodland, while the postreclamation condition was one of a compacted, bulldozed soil. Sediment concentration results were influenced by failure of the postreclamation erosion control system and by a series of detention reservoirs above the stream monitoring station.

Water quality as affected by surface coal mining was monitored by measuring 38 parameters in 59 surface-water samples. Comparisons of parameter concentrations in samples collected at similar flow rates during the premine (Phase 1) and the reclaimed (Phase 3) periods showed that concentrations were generally increased in the reclaimed samples. Suspended solids concentrations exceeded the OSM regulation level (70 mg/l) during all three phases but were extremely high during active mining and reclamation (Phase 2). Manganese concentrations exceeded the OSM regulation level (4 mg/l) during Phases 2 and 3 and 20% of the pH values during Phase 2 were below the lower regulation level of 6.0. Topsoil, 4-26 inches in thickness, was dominantly loam and silt loam in texture with 15-23% coarse fragments (2 mm). Spoil was loam in texture with an average of 52% coarse fragments. pH values averaged 5.0-6.0 in both topsoil and spoil. The soils were classified as various slope phases of Fairpoint; a loamy-skeletal, mixed, nonacid, mesic Typic Udorthent.

U.S. Bureau of Mines. 1983a. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase 3: Hydrologic and Water Quality Conditions after Reclamation in a Small, Mined Watershed, Muskingum County, Ohio. U.S. Bureau of Mines Open-File Report, 196 pp.

Abstract

A 43-Ac Ohio watershed on chiefly calcareous materials was mined for coal during 1977 and 1978. Surface and subsurface hydrology and water quality were monitored continuously beginning 6 months before mining and ending 28 months after reclamation was completed. Based on logarithmic-normal fits of nearly 40 years of records, the study period was cool and wet, with precipitation generally increasing throughout the period of record. Sediment production increased drastically during active mining, but even partial reclamation was highly beneficial. Full reclamation lowered sediment production to or below premine levels, although sediment for either exceeded Office of Surface Mining limits. The data yielded no evidence that storm runoff was affected by surface mining. Baseflow declined because of destruction of an aquifer above the mined coal. After reclamation, the aquifer began to redevelop, but was not replenishing baseflow by the end of the study. Water in the new aquifer was higher in sulfate than before mining, and a deeper aquifer was beginning to show an increase in sulfate.

Water quality as affected by surface coal mining was monitored by measuring 38-constituents in 55 surface water samples. Comparisons of constituent concentrations in samples collected at similar flow rates during the premine (Phase 1) and the reclaimed (Phase 3) periods showed that concentrations were not significantly different or were decreased in the reclaimed samples. Suspended solids concentrations exceeded Office of Surface Mining regulation level (70 milligrams/liter) during all three phases, but were extremely high during active mining and reclamation (Phase 2). Reclaimed topsoil, 8-14 inches in thickness, was predominantly silty clay loam in texture and generally contained less than 10% coarse fragments (>2 mm). Clay content of the spoil was less than 40% and coarse fragments content ranged from 10 to 90%. The majority of the topsoil and spoil material had a pH value greater than 7.0 and had free carbonates. The soils were classified as various slope phases of Morristown; a loamy-skeletal, mixed (calcareous) mesic Typic Udorthent.

U.S. Bureau of Mines. 1982b. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase 2: Hydrologic and Water Quality Conditions during Mining and Reclamation in a Small Watershed in Muskingum County, Ohio. U.S. Bureau of Mines Open-File Report, 138 pp.

Abstract

The Meigs Creek (Sewickley) No. 9 coal was mined, and reclamation operations were completed on Watershed M09 during the period January 9, 1977 to September 11, 1978. Surface area was reduced from 43.5 to 36.8 Ac and total relief was reduced from 233 to 146 ft. The saturated water zone above the coal underclay was destroyed and emptied of water, resulting in lower, more highly mineralized baseflow from the middle aquifer only. For events producing 0 to 1 in total rainfall, surface runoff totals for Phase 2 reached as much as 20 times the totals observed for similar rainfall events in Phase 1. Water in the middle and lower aquifers was not significantly affected in either quantity or quality in Phase 2. Sediment concentration in surface runoff was highly variable, especially during mining, and, for the same range of flow rates, exceeded Phase 1 values by about two orders of magnitude. Reclamation had an effect even before completion. Seventy percent of reclamation period flows contained sediment at levels equal to or less than 12,005 mg/l. For the mining period, the equivalent level was 75,000 mg/l.

During the mining period (Phase 2) various chemical parameters were measured in surface water, precipitation, and suspended sediment samples. Concentrations of suspended solids, color, selenium, carbon dioxide, and sulfate in surface water samples collected at the watershed outlet during Phase 2 were substantially increased compared to concentrations found in Phase 1 (premining) water samples. Parameters generally not detected during Phase 2 were cadmium, antimony, silver, lead, arsenic, cyanide, sulfide, chromium, and mercury. Bicarbonate, alkalinity, and barium concentrations were decreased during Phase 2. Parameters measured in precipitation which equaled or exceeded concentrations found in surface water samples were aluminum, copper, iron, nitrate, zinc, phosphorus, and barium. Analyses of suspended sediment collected at the watershed outlet showed that during Phase 2, dilute HC1-soluble calcium, magnesium, and strontium concentrations were significantly increased over Phase 1 concentrations while copper was only slightly increased in concentration.

U.S. Bureau of Mines. 1982a. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase 2: Hydrologic and Water Quality Conditions during Mining and Reclamation in a Small Watershed in Coshocton County, Ohio. U.S. Bureau of Mines Open-File Report, 130 pp.

Abstract

The Middle Kittanning, No. 6 coal was mined, and reclamation operations were completed on Watershed C06 during the period November 4, 1976 to October 23,1978. Surface area was reduced from 49 to 41 Ac and total relief was reduced from 265 to 191 feet. The saturated water zone in and above the coal was destroyed and emptied of water, resulting in lower, more highly mineralized baseflow from the middle aquifer only. Phase 2 (during mining and reclamation) surface runoff totals were somewhat higher than those of Phase 1 (premining). Water in the middle and lower aquifers was not significantly affected in either quantity or quality in Phase 2. Sediment concentration in surface runoff was highly variable and, for nearly the same range of flow rates, exceeded Phase 1 values by about 30 times. A sediment pond at the outlet exhibited a trap efficiency of 98%.

During the mining period (Phase 2), various chemical parameters were measured in surface water, precipitation and suspended sediment samples, respectively. Concentrations of suspended solids, sulfate, manganese, color, selenium, calcium, hardness, magnesium, dissolved solids, carbon dioxide, strontium and chloride in surface runoff water samples collected at the watershed outlet during Phase 2 were substantially increased compared to concentrations of these parameters found in premining (Phase 1) water samples. Parameters that generally were not detected at the watershed outlet during Phase 2 were cadmium, antimony, silver, lead, arsenic, chromium, cyanide, sulfide and mercury. Bicarbonate concentrations were decreased during Phase 2. Parameters measured in precipitation which equaled or exceeded concentrations found in surface water samples were aluminum, cooper, nitrate, and zinc. Analyses of suspended sediment collected at the watershed outlet showed that during Phase 2, dilute HC1-soluble sulfate was significantly increased over Phase 1 concentrations, while manganese, magnesium, iron, copper, and nickel concentrations were only slightly increased.

U.S. Bureau of Mines. 1978. Research on the Hydrology and Water Quality of Watersheds Subjected to Surface Mining. Phase 1: Premining Hydrologic and Water Quality Conditions. U.S. Bureau of Mines Open-File Report 88-80. 347 pp.

Abstract

Five watersheds, ranging in size from 29 to 52 acres, were selected in east-central Ohio to investigate the hydrologic and water quality conditions occurring before, during, and after surface mining. Field equipment was installed to obtain runoff, weather and soil moisture data, and to collect runoff and precipitation samples. Base line data were also collected on soils, vegetation, and geology.

Baseflow and storm runoff water samples from four of the unmined watersheds were collected and analyzed quantitatively for 39 water quality parameters. Monthly precipitation samples and sediment fractions of the baseflow and runoff were analyzed for 22 and 17 parameters, respectively.
